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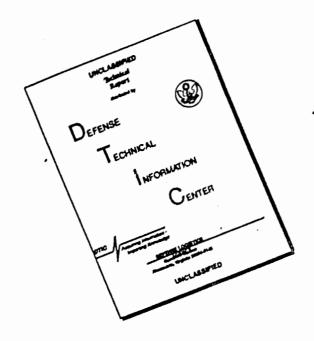
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# NAVAL AIR MATERIAL CENTER PHILADELPHIA 12, PENNSYLVANIA

# AERONAUTICAL MATERIALS LABORATORY

REPORT NO. NAMC-AML-1291

DATE 25 September 1961

A STUDY OF THE SHORT TIME ELEVATED TEMPERATURE PROPERTIES OF CLAD X2020-T6 AND 7075-T6 ALUMINUM ALLOY SHEET

PROBLEM ASSIGNMENT NO. C 10 RMA 21-10 (FORMERLY AE 41117 - MA 2028) UNDER BUREAU OF NAVAL WEAPONS WEPTASK RRMA 02 018/200 1/ROC: 05 002

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Approved by:

Head,

Mechanical Metallurgy Branch

Superintendent, Metallurgical Division

## ABSTRACT

Short exposure time tensile tests were performed on clad 7075-T6 and clad X2020-T6 aluminum sheet. The exposure temperatures used were 300°F, 350°F, 400°F, 450°F, and 500°F. The exposure times were 3, 10, 30, 60, and 600 seconds. Specimens were tested at temperature and at room temperature after exposure. The strain rates used were 0.002 and 0.054 inches per inch per minute.

## I. INTRODUCTION

- A. This investigation was conducted to obtain data for use in establishing the effect of nuclear v and blasts on aircraft skin materials. The environment produced by such blasts is rapid radiant heating followed by shock wave loading. The obvious need was for tensile data after rapid heating and short exposure. Data of this type is limited since for most applications exposure times of 1/2 hour are the shortest reported. Therefore, reference (a) established this project for the purpose of obtaining the required short-time tensile data for clad aluminum alloys X2020-T6 and 7075-N6.
- B. The work done under reference (a) was divided into two parts. The first part consisted of the investigation and development of methods for rapid and uniform heating of aluminum alloy specimens by the use of programmed high-intensity quartz heat lamps. In addition, techniques for measuring the load imposed on the specimen and the specimen elongation under load during rapid loading were developed. This work was performed by the Aeronautical Structures Laboratory (ASL), Naval Air Material Center, Philadelphia, Pa., and is reported in reference (b). The second part of the work consisted of the collection and analysis of short exposure time tensile data and is reported herein.

# II. SUMMARY OF RESULTS

- A. The data obtained from tensile tests of specimens exposed to elevated temperatures for short times (3 to 600 seconds) are shown in Plates 1 to 12 inclusive and Table 1.
- B. In general the changes in tensile strength properties observed during this investigation were those which are to be expected in an age-hardened material.
- C. Specimens exposed to several thermal pulses in general have the same strength properties (Plate 13) as specimens exposed to a single pulse equal to the sum of the times of the several pulses.

# III. CONCLUSIONS

- A. In the alloys studied the observed results were those which are to be expected in an age-hardening material; that is, a slight increase in strength properties after short exposures followed by a decline in these properties on longer exposure.
- B. For all comparable conditions the clad X2020-T6 aluminum alloy exhibited ultimate tensile and yield strengths superior to those for clad 7075-T6 aluminum alloy.

# IV. RECOMMENDATIONS

A. It is recommended that the data obtained in this investigation be used where the design criteria is short time tensile strength for elevated temperature applications.

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- 13 Strength Properties of Clad 7075-T6 Aluminum Sheet at the Indicated Temperatures as a Function of Number of Thermal Pulses Quartz Lamp Heating
- 14 Photograph of Tensile Test Specimens
- 15 Photomicrograph of Section Through Area of Ultrasonic Weld

### V. TEST CONDITIONS

- A. Three series of tensile tests were conducted. In the first series, the specimens were exposed to various temperatures in molten salt before testing at room temperature at a normal strain rate (0.602 in./in./min.). The two remaining series were exposed to the various temperatures via radiant heat lamps for the required times. One of the latter series was tested at the end of the exposure period at a fast strain rate (0.054 in./in./min.). The other series was cooled to room temperature then tested at the fast strain rate.
- B. In all cases triplicate tests were run and an average result is reported. The two types of specimens used in these tests are shown in Plate 14. The thermocouples attached to the specimens heated by quartz lamps, were ultrasonically welded in place. The effects of the ultrasonic weld do not extend through the cladding of the materials used, as shown in Plate 15. Therefore, no adverse effects were expected and none were observed.
- C. The specimens exposed in molten salt were clad 0.040 inch 7075-T6 alloy and clad 0.063 inch X2020-T6 alloy. Before the specimens were dipped the bath was stirred and the temperature read by means of a thermocouple and a portable potentiometer. The times necessary for the specimens to reach temperature were found using a thermocouple attached to a specimen and a high speed recording potentiometer. The specimens were then exposed for times at temperature of 3 sec., 10 sec., 30 sec., 60 sec., and 10 minutes. The exposure temperatures used were 300°F, 350°F, 400°F, 450°F, and 500°F. After exposure, the specimens were tensile tested at room temperature at a strain rate of 0.002 inches per inch per minute. Ultimate tensile strength, 0.25 yield strength, and total elongation in 2 inches were calculated and recorded.
- D. The materials used in the radiant heat lamp series were 0.063 inch clad X2020-T6 and 7075-T6. A complete description of the equipment and techniques used in these tests may be found in reference (b). The specimens were held at temperature 3 sec., 10 sec., 30 sec., 66 sec., and 10 minutes. Tables 2 and 3 give indications of the accuracy of temperature control and of temperature distribution along the specimen. They were then tested immediately or cooled to room temperature for testing. The exposure temperatures used were 300°F, 350°F, 400°F, 450°F, and 500°F. The strain rate used for these tests was 0.054 in./in./min. Ultimate tensile strength and 0.25 yield strength were calculated from the data obtained.
- E. To simulate the effect of nuclear blast on claim 7075-T6 aluminum alloy several specimens were exposed to radiant heat pulses of three seconds duration at either 300°F or 400°F. Specimens were exposed to 1, 2, 4, and 8 pulses. After each pulse (except the final one) the specimen was cooled to ambient temperature. After the final pulse the specimens were tensile tested at temperature at a strain rate of 0.05% inch per inch per minute.

# VI. ANALYSIS OF TEST RESULTS

- A. The results of the short time at temperature exposure tensile tests performed during this investigation are shown in Flates 1 to 12. For comparison purposes data normally obtained from the as-received material at room temperature are included in the plates. In a significant portion of the data, the maximum tensile values occur after exposures of 10 to 30 seconds. Note should be taken of the fact that this effect was observed both in specimens exposed in salt and those exposed to radiant heat. Therefore, the effect seems to be due to the heating alone and not to the method of heating or strain rate. Thus, the apparent cause of the maximums would be a continuation of the age-hardening reaction.
- B. Except for these maximum points discussed above, the material behaves as would be expected. That is, as the exposure time at temperature and the temperatures are increased, the tensile strength properties decrease.
- C. Plate 13 shows the data obtained from specimens exposed to thermal pulses. Comparison of this data with the data given in Plates 5 and 6 show that the tensile values are approximately the same for a given total exposure.

# **FEFERENCES**

- (a) BUAER 1tr Aer-AE-415/223 of 12 Nov 1959
- (b) Report No. NAMC-ASI-1040

ELONGATION OF CLAD 7075-T6 AND X2020-T6 ALUMINUM SHEET TESTED
AT ROOM TEMPERATURE AFTER EXPOSURE IN MOLTEN SALT
STRAIN RATE 0.002 "/" MINUTE

Exposure Temperature	Exposure Time, Sec.	7075-T6 Elongation in 2 inches, %	X2020-T6 Elongation in 2 inches, %
300°F	3 10 30 60 600	11 J2 12	7 6 
350°F	3 10 30 60 600	11 11 12 12 11	7 7 6 6 6
400°F	3 10 30 60 600	12 13 11 10 10	7 6 6 6
450 <b>°F</b>	3 10 30 60 600	11 12 10 11	7 7 6 6 7
5 <b>∞°</b> F	3 10 30 60 600	9 9 11 10 11	8 7 6 7

TROPERATURES AT THE END OF ELLYSURE TIMES

	Specimen	Thermocouple	Exposur	e Tine an	Exposure Time and Specimen Temperature	n Tempera	ture
Temperature Programmed	Designation Munber	Number and Location	3 Sec.	10 Sec.	30 Sec.	60 Sec.	10 Min.
300eF	109 135 31 136 103	No. 3 - Center n n n n	308 308 305	299 315 302	305	295 299	662
350°F	26 25 22 17 19		353 363 351	351 360 370 370	351 360 357	351 351	351
₫-007	52 53 54 57 302		412	399 412 412	402 409 412	007 707	007
å=057	3% 8 7 7		751 767 788	451 457 463	757 757 757	757 778 778	8777
300eF	304 312 140 108 101		500 512 484	967 967 968	787	485	167

TABLE 2

UNIFCRMITY OF TEMPERATURE IN SPECIMENS

						Sr	pect	men										
	T	<b>36</b> t				Te	<b>8</b> t	2			Te	est	3		Ţ	rest 4	7	
E/C No.	3 Sec.	•	<b>S</b> 9	00	3	Sec.	••	6 30	3	3	Sec	••	6 Sec.	••	3 Sec	•	6 S	ပ္စ
	••	••			••		••		••			••		••		••		
Top 1	••	••			••	E	100	BEERO	d fe	Ŀ	Programmed for 350°F	••		••		••		
	••	••			••		••		••			••		••		••		
Center 3	: 347	••	m	367	••	347	••	367			347	••	367	••	347	••	367	_
		••	•	•	••	100	••	č	••	. `	,	••	;	••	Č	••	,	
Bottom 4	363	••	う	741	••	782	••	74	 . <del>.</del>	,,	782	••	7	••	787	••	747	_
••		••			•		•		•			•		•			•	•

•	••	Sec.:	••	••	••	380	••	334 :	••
	Test 5	. :6 Sec.	••	••	••	••	••	••	••
	T	3 Sec.				373		373	
			•••	••	••	••	••	••	••
,	7:	6 Sec.				380		334	
	rest A	**	••	••	••	••	••	••	••
	I	3 Sec.				323		376	
		**	••	••	••	••	••	••	**
	Test 3	: 6 Sec.		Programmed for 350°F		376		334	
	res		••	Cor	••	••	••	••	**
Specimen B		3 Sec.		peum		32		373	
3			••	5	••	••	••	••	••
Sp	; 2	6 Sec.		ř		376		331	
	98	••	••	••,	.00	••	••	••	4
		3 Sec.				33		367	
		••	••	••	••	••	••	••	-
	1	6 Sec.				8		328	
	ss t	*	••	••	••	••	•1	••	-
	T	3 Sec.			••	347		 %	
						3		4	
,		T/C No.		Top 1		Center 3		Bottom 4	

TABLE 3

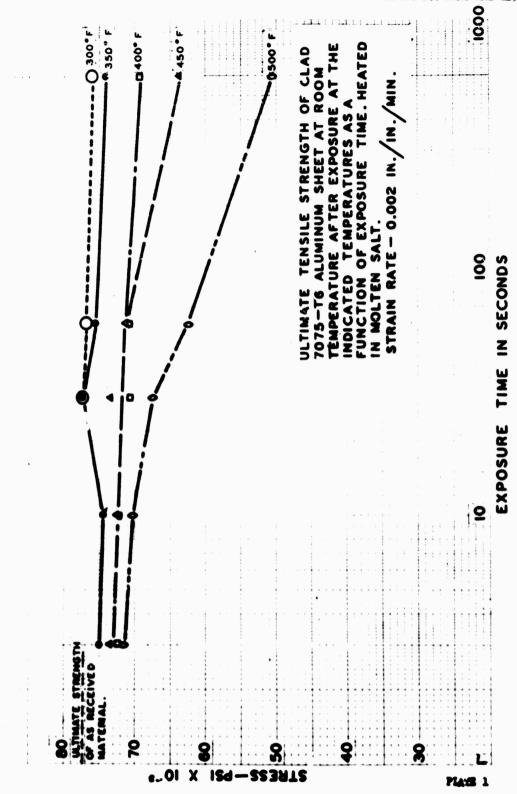


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PLATE 1

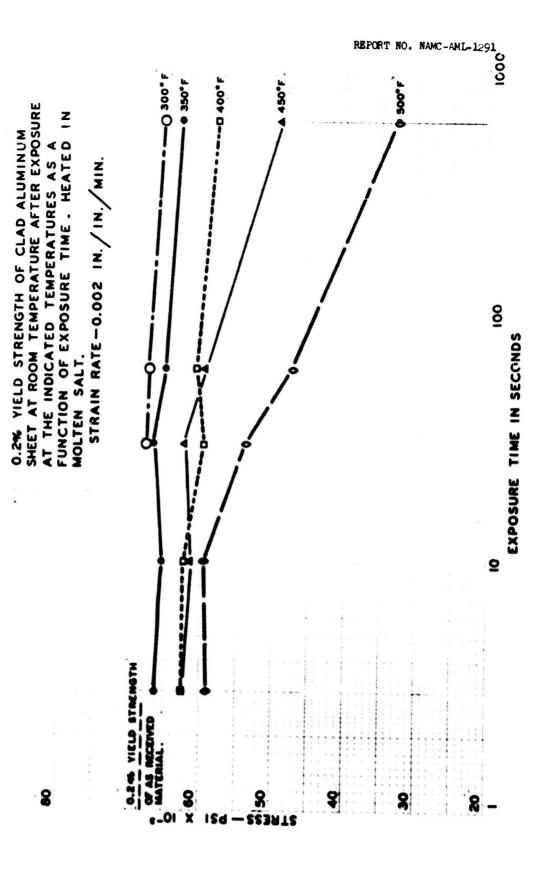
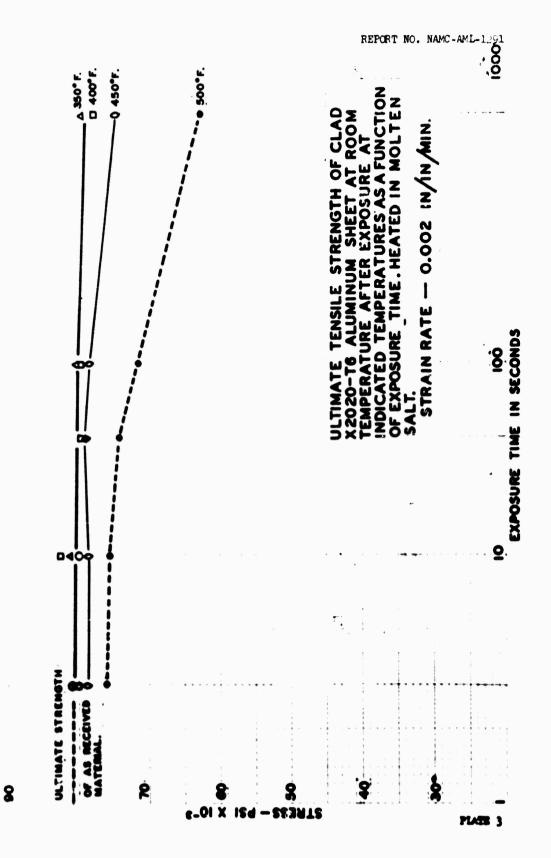


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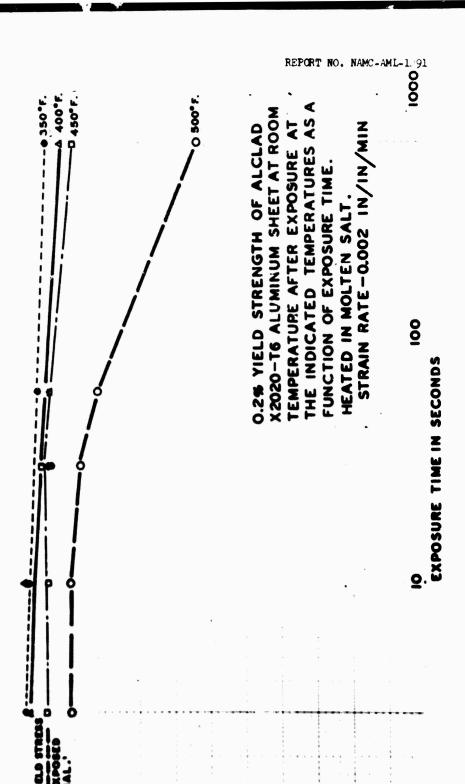


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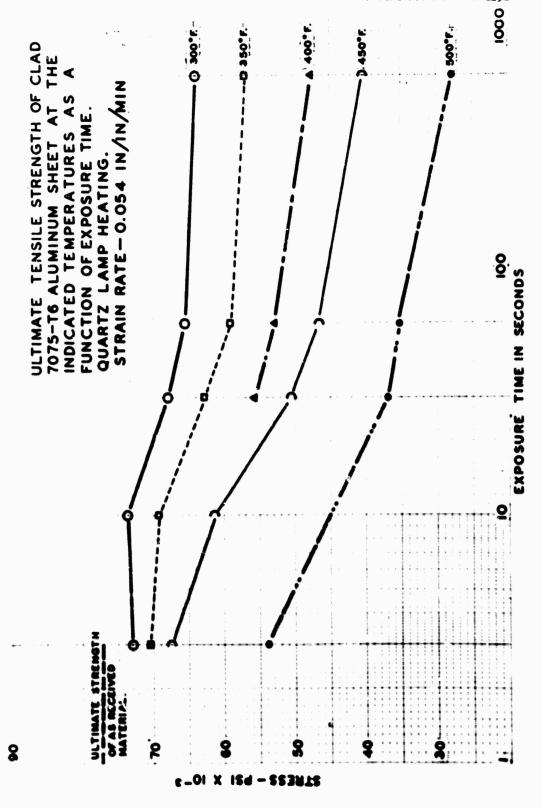


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PLATE S

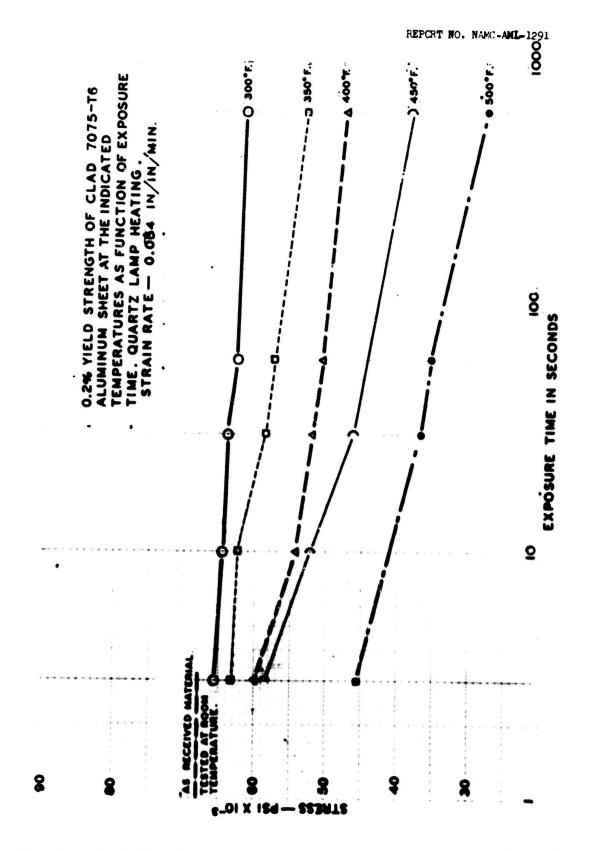


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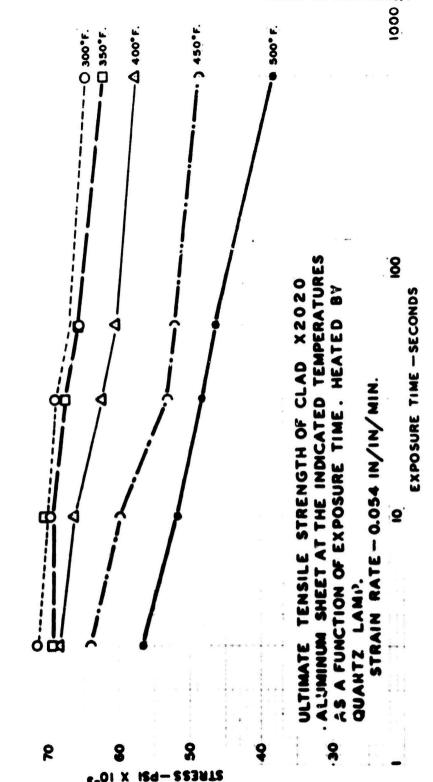


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TESTED AT ROOM TEMPERATURE

8

PLATE 7

PHOTO NO: CAN-339349(L)-9-61

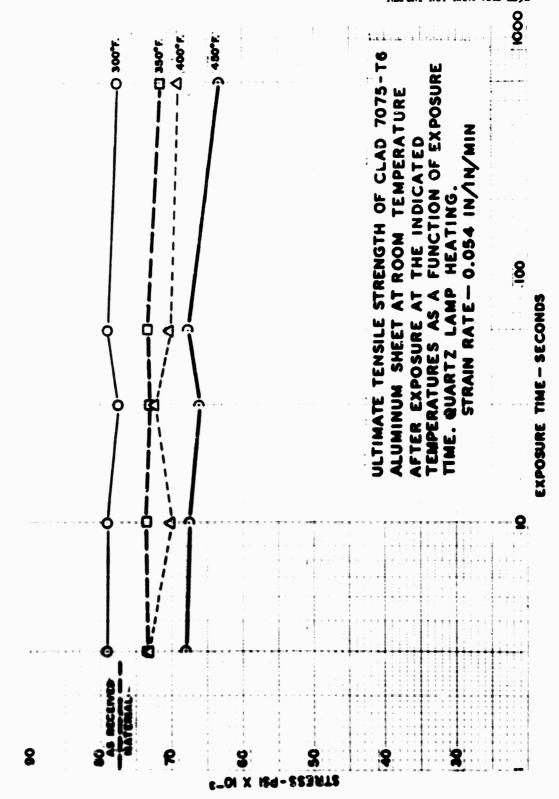


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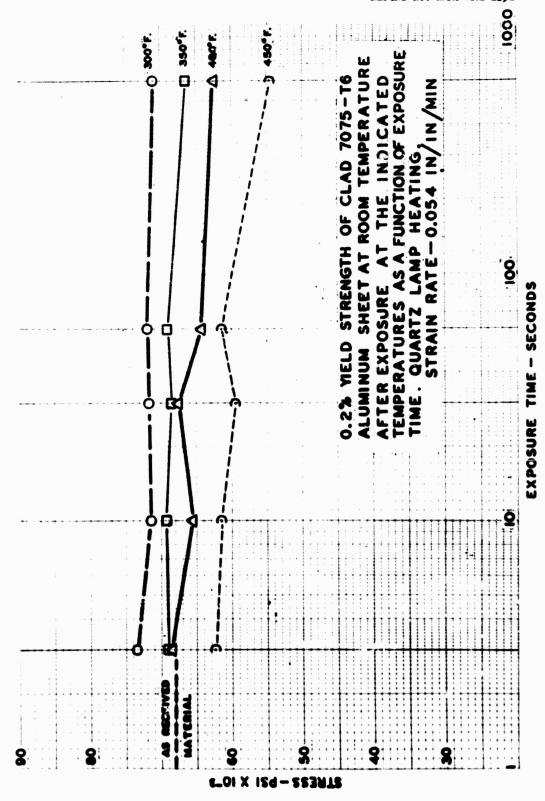
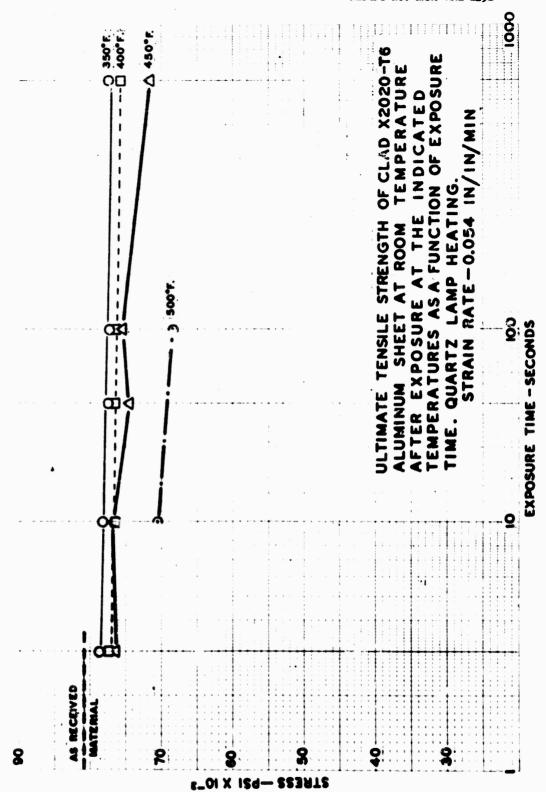


PHOTO NO: CAN-339351(L)-9-61



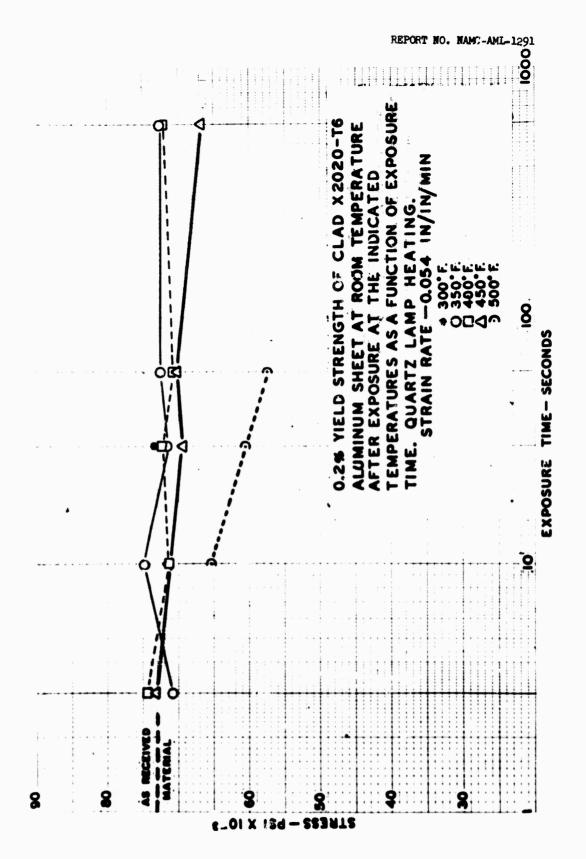


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PLATE 12

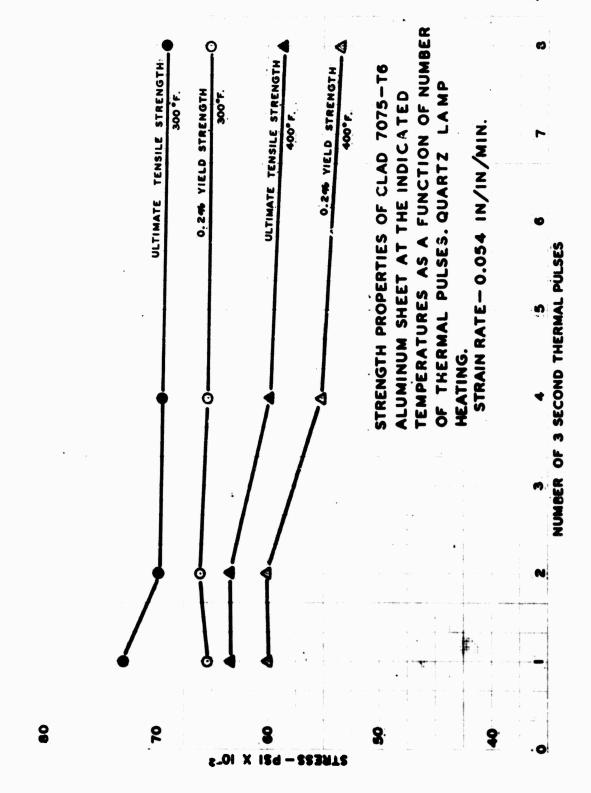


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# PHOTOGRAPH OF TENSILE TEST SPECIMENS





Fig. 2 - Specimen used in quartz 'a np exposure

Fig. 1 - Specimen used in molten salt exposure

PHOTO NO: CAN-339355(L)-9-61

PLATE 14

# PHOTOMICROGRAPH OF SECTION THROUGH AREA OF ULTRASONIC WELD



MAG: 100X

Keller's Etcn

PHOTO NO: CAN-339356(L)-9-61

1. REPORT NAMG-AML-1291 2. PAN C 10 RMA 21-10 (AE 41117-MAZ028) U. S. MAYAL AIR MATERIAL CENTER, PHILA., PA. Aeromautical materials laboratory

A Study of the Short Time Elevated lempurature Properties of Slad X2020-16 and 7075-16 Aluminus Alley Specis by R. G. Mehorter, October 1961, 13 p., 15 Plates Mort emposure time tensity tests were performed on elad 7075-16 and elad E2020-16 aluminum sheet. The exposure temperatures used were 30009, 35007, 40009, 45009, and 50009. The exposure times were 3, 10, 30, 60 and 600 seconds. Specimens were tested at temporature and at room temporature ofter exposure. The strain rates weed were 0.002 and 0.054 in hee per inch per aimete.

U. S. NAVAL AIR MATERIAL CENTER, PHILA., PA. AERONAUTICAL MATERIALS L'BORATORY

1. REPORT NAMC-AML-1291 2. PAN C 10 RMA 21-10

(AE 41117-MA 2028)

Temperature Properties of Clad X2020-15 and 7075-16 Alusinum Aldoy Sheet; by R. G. Mahorter, A Study of the Short Time Elevated October 1961, 13 p., 15 Plates

temperatures used were 3000F, 3500F, 4000F, 4500F, and 5000F. The exposure times were 3, 10, 30, 60 and 600 seconds. Specimens were tested at temperature and at room temperature Short exposure time tensile tests were performed on clad 7075-16 and clad X2020-16 aluminum sheet. The exposure after exposure. The strain rates used were 0.002 and 0.054 inches per inch per minute.

> AILA., PA. U. S. BAYAL AIR BATERIAL CENTER, "ACROBANTICAL BATERIALS LABORATORY

A Study of the Bort Time Elevited Temperature Proportion of Clam 12020-16 and 7075-16 Aluminum Alloy Brott b. R. 6. Mahortor, Detobor 1961, 13 p., 15 Plates Short exposure time tensile tests were performed on class 7075-76 and clad E2020-16 aluminum about. The exposure temperatures used were 3000F, 350PF, 400FF, 450PF, and 5000F. The exposure times were 3, 10, 30, 60 and 60% accords. Specimens were tested at temperature and at rece temperature after exposure. The atrain rates used were 0.002 and 0.054 inches per inch per sinute.

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REPORT HANG-AM-1291

PAN C 10 RMA 21-10 (AE 41117-MA 2028)

A Study of the Short Time Elevated Temperature Properties of Clad X2020-T5 and 7075-T6 Aluminum Alloy Sheet; by R. G. Mahorter, October 1961, 13 p., 15 Plates

Short exposure time tensile tests were performed on clad 7075-T6 and clad X2020-T6 aluminus Sheet. The exposure temperatures used were 3000F, -3500F, 4500F, 4500F, and 5008F. The exposure times were 3, 10, 30, "60 and 600 seconds. Specimens were tested at temperature and at room temperature after exposure. The strain rates used were 0.002 and 0.054 nches per inch per sinute.

1. REPURT NAMC-AML-1291 2. PAN C 10 RMA 21-10 (AE 41117-MA 2026)